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ABSTRACT

The Computer-Supported Intentional Learning Environments (CSILE) database has been developed to support students' progressive discourse. Students can externalize their thoughts in the database in the form of texts or graphics, and then they can manipulate their represented knowledge in building further knowledge. They can asynchronously collaborate and add reflective thoughts to their friends' work. The present study examined two fifth- and sixth-grade combined classrooms using different types of systems in two consecutive years. In the first year, 29 students used a CSILE version in which they reported their thoughts on the study topic, electricity, in individual text or graphic notes. In the second year, 27 students used another version in which they reported notes on the topic of force in discussion notes with proposed problems. Basic skills were not different in the two samples, but students in the second year were more engaged in knowledge-transforming information flow and more able to manipulate different types of externalized knowledge in their written discourse. Two appendixes contain examples of knowledge discourse and knowledge changes. (Contains 1 table, 6 figures, and 24 references.) (SLD)

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Differences in Knowledge-Building between Two Versions of CSILE: An Information-Flow Analysis

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Introduction

As Bereiter (1994) argued, what is missing in traditional classroom learning is students' engagement in activities of generating ideas superior to previous ones through their discourse. "Computer-Supported Intentional Learning Environments (CSILE)" has been developed for supporting such students' progressive discourse. Students are allowed to externalize their thoughts in the database in the form of texts or graphics, then manipulate their represented knowledge in building further knowledge. The database is accessible to anyone who is registered as a member. Students can asynchronously collaborate through mutual commentaries. They can create comment notes to add their reflective thoughts on their friends' thoughts. Thus, students with CSILE work as members of the classroom community in pursuing their inquiries on study topics (Scardamalia, Bereiter, Brett, Burtis, Calhoun & Smith-Lea, 1992). Although evaluative data have indicated that CSILE prompts students' engagement in their own and others' knowledge as cognitive resources, sustaining progressive discourse has been still problematic (Scardamalia, Bereiter & Lamon, 1994). The aim of the present study is, therefore, to examine how students' discourse happens and progresses in CSILE by inspecting details of how students manage their available information in the database.

To pursue the above research question, the present study examined two fifth- and sixth-grade combined classrooms taught by the same teacher which used different types of systems in two consecutive years. In the first year, twenty-nine students used a version of CSILE (the "first-year system") in which they reported their thoughts on a study topic, electricity, in their individual text or graphic notes. Hence, the database was a compilation of such individual notes. Students organized and advanced their own and others' thoughts by accessing and commenting on the notes. In the second year, twenty-seven students used another version (the "second-year system") in which they reported their thoughts on a study topic, force, through dialogical written discourse on their collaborative problems in *discussion* notes. In discussion notes, students proposed problems to pursue and reported their thoughts related to the problems (Figure 1). In each year, before starting their CSILE learning session, they conducted classroom experiments and group work based on materials available in the classroom. The teacher in the classroom helped and encouraged students to collaborate with one another through the database system.

Insert Figure 1 about here

As an analytic tool for students' discourse in CSILE, I use a new concept of human cognition by Perkins (1993). From the perspective of distributed cognition, Perkins (1993)

proposed a new level of analysis of human mind, *cognition as information-flow*. He defined *person-plus-surrounding* as a unit of analysis of cognition, and focused on information-flow in the *person-plus-surrounding* system. Here, the focus of the analysis is no longer on how subjects' internal structures are constructed, but rather on how subjects work in the global system. To describe the information-flow in a target global system, Perkins suggested the following information-access characteristics of the system:

Knowledge. When the global cognitive system functions in a task, various types of knowledge are used, from content-specific knowledge to higher-order knowledge such as monitoring and planning. In the present study, I focus on different types of descriptive knowledge in the database.

Representation. How knowledge is represented is another important aspect. Because CSILE is mainly driven by written discourse, I focus on the written form of knowledge.

Retrieval. Although desired knowledge is represented in the system, we cannot always access it in a contextually appropriate way. Studies have shown: (1) that experts usually learn necessary knowledge and skills in a quite problem-based situation so that they can easily access the necessary knowledge in their work (e.g., Brown, Collins & Duguid, 1989); and (2) that authentic problem-based learning in a meaningful context can prompt learners' acquisition of knowledge which can be later retrieved in an appropriate way (e.g., Lampert, 1986). Here, I focus on (1) how learners use their own and others' knowledge represented in the database, and (2) how they manipulate the knowledge in advancing their progressive discourse.

Construction. "Construction" means the system's information processing, such as assembling pieces of represented or retrieved knowledge. Recent studies on *effects with intellectual technologies* (Salomon, Perkins & Globerson, 1991) showed that computer support which allows learners to run and see their represented knowledge improves the learners' reflective processes in problem solving and helps them acquire higher levels of understanding (e.g., Nathan, Kintsch & Young, 1992). Here, I focus on two different planes of collaborative learning in which students engage in their learning in CSILE.

Study Design

Data Source

Students' computer actions, such as text- and graphic-generation and revision were automatically recorded as tracking files on a hard disk of a main server (Figure 2). Information used in the present study contained time and contents of text- and graphic-

generation, revision, and database search. Based on the above information, the present study examined how students represented and manipulated the knowledge in the database.

Insert Figure 2 about here

Measures for Students' Basic Skills Related to Written Discourse Activities in CSILE

Students' basic skills related to their written discourse activities in CSILE were considered to affect their use of the system. Scores of reading, writing, and spelling in the Canadian Tests of Basic Skills (King-Shaw, 1988) conducted at the beginning of the academic year were used as measures of students' basic skills.

Measures for Information-Access Characteristics in CSILE

Construction. Students are considered to engage in two different planes of collaborative learning: the solo-plane and the joint-plane. The solo-plane is a constructive arena where students develop their own understanding. Students' activity in the solo-plane was examined by analyzing change in their written discourse from their own preceding discourse. The joint-plane is another arena where students contribute to the development of understanding in the classroom community. Activity in the joint-plane was examined by analyzing change in students' written discourse from others' preceding discourse, and students' commentaries on others' discourse. Besides using the same measures as those in the solo-plane, I counted the number of joint sessions in which each individual student searched and accessed others' notes.

Knowledge. Students' written discourse in each note was divided into units of ideas, then each unit was categorized as one of three types of knowledge items. The first is *referent-centred* knowledge (Bereiter, 1992). This is definitional and descriptive information which clearly refers to a concept. It is easy for students to pick out this type of knowledge from their resource materials or their minds. The second is *problem-centred* knowledge (Bereiter, 1992). This is process-oriented information, such as causal mechanisms which have potential to facilitate students' understanding. Recent research on students' conceptual change (e.g., Chi, de Leeuw, Chiu & Lavancher, 1994; diSessa, 1993; Smith, diSessa & Roschelle, 1993) has suggested that problem-centred learning in which students authentically engage in building knowledge based on their everyday experiences is critical to facilitating children's conceptual change in science education. The third is *metacognitive* or *reflective* knowledge. Although it has been considered to appear rarely in an external form (Perkins, 1993), students, here, were asked to write down their reflections on their own learning. For instance in Figure 2, a student reported five sentences in a note. According to the coding scheme here, the first three sentences were

categorized as a referent-centred knowledge item, then the last two sentences were categorized as a problem-centred knowledge item. Frequencies of knowledge items were counted in the solo-plane. In the joint-plane, frequencies of knowledge items students accessed in their joint sessions were counted, based on the tracking files. Accessed notes or knowledge items were defined so, if they were opened in students' computer monitors for more than ten seconds. Then, the proportion of each type of knowledge items students responded to through integrating into a new idea or commenting was calculated by dividing the frequency by the total frequency of each type of knowledge item. Two independent raters identified and categorized the units of ideas (inter-rater agreement was over 90%), then frequencies of the categories were counted.

Retrieval. To analyze how learners manipulated knowledge represented in the database, two types of knowledge-changes from one knowledge item to another were identified: (1) *knowledge-widening*, and (2) *knowledge-deepening* (See an example of a structure of knowledge-building discourse in Appendix A). Knowledge-widening means that a new knowledge item develops by assimilating information in a preceding knowledge item. Knowledge-deepening means that a new knowledge item develops by accommodating information in a preceding knowledge item. Two independent raters identified eight types of knowledge-changes (inter-rater agreement was over 90%), then proportions of knowledge items which belong to the eight categories of knowledge-changes were calculated in either the solo-plane or the joint-plane (See Table 1 for the eight categories of knowledge-changes. Examples are also included in Appendix B.). Particularly from the perspective of progressive discourse as knowledge-building, I was interested in how the two systems support students transform knowledge in written discourse. Studies of writing (e.g., Hayes & Flowers, 1980; Bereiter & Scardamalia, 1987), discourse comprehension (e.g., van Dijk & Kintsch, 1983), and scientific reasoning (e.g., Klahr & Dunbar, 1988) have so far suggested that knowledge transformation between different problem spaces is critical to effective problem solving. In classroom learning studied here, the transformation was considered to happen between referent-centred and problem-centred knowledge.

Commenting is another measure for us to examine how students manipulate others knowledge to contribute to the development of their classroom knowledge. Because of small-sample problem, students' commentaries were categorized on the basis of their potential of contribution as follows: (1) *knowledge widening oriented*, (2) *knowledge deepening oriented*, or (3) *information based*. Knowledge widening and knowledge deepening oriented commentaries mean commentaries which have potential to change target knowledge items in knowledge-widening and knowledge-deepening ways, respectively. Information-based commentaries are

those which evaluate surface information in written discourse, such as grammatical errors and misspelling.

Insert Table 1 about here

Results and Discussion

Comparison of Students' Basic Skill Scores

A one-way MANOVA on the three basic skill scores showed no significant results (Wilks' Lambda was .87, $p > .05$). Thus I concluded that students' basic skills were not significantly different between the two samples of students.

Comparison of Frequencies of Knowledge Items Generated by Students

A 2 (Type of CSILE) X 3 (Type of Knowledge) ANOVA showed a significant main effect of Type of Knowledge and a significant effect of an interaction, $F(2, 108) = 61.7$ and $F(2, 108) = 4.9$, respectively, $ps < .05$. *Post hoc* comparisons by LSD test showed that students in the second-year system represented significantly more problem-centred knowledge items (Figure 3).

Insert Figure 3 about here

Comparison of Knowledge-Change in the Solo-Plane

Because students mainly manipulated referent-centred and problem-centred knowledge items, I focused my analysis on the two types of knowledge items. Multiple *t*-test comparisons of proportions of knowledge-changes in the solo-plane showed the following: (1) students in the second-year system manifested significantly greater proportions of widening change in referent-centred knowledge from problem-centred knowledge, $t(48) = -2.0$, and the students also showed greater proportions of deepening change in problem-centred knowledge from referent-centred knowledge, $t(48) = -3.7$, $ps < .05$, and (2) students in the first-year system manifested significantly more widening change in problem-centred knowledge from problem-centred knowledge, $t(43) = 2.9$, $p < .05$ (Figure 4).

Insert Figure 4 about here

Comparison of Knowledge-Change in the Joint-Plane

Because of small-sample problem, a categorical data analysis was carried out. Chi-square analyses on frequencies of students showed the following: (1) more students in the

second-year system showed widening change in referent-centred knowledge from others' problem-centred knowledge, $\chi^2(1, N = 56) = 10.0$, $p < .05$; (2) marginally, but not significantly more students in the second-year system showed deepening change in referent-centred knowledge from others' referent-centred knowledge, $\chi^2(1, N = 56) = 2.7$, $p < .10$; (3) more students in the second-year system showed deepening change in referent-centred knowledge from others' problem-centred knowledge, $\chi^2(1, N = 56) = 8.6$, $p < .05$; (4) more students in the second-year system showed widening change in problem-centred knowledge from others' referent-centred knowledge, $\chi^2(1, N = 56) = 4.5$, $p < .05$; (5) more students in the second-year system showed widening change in problem-centred knowledge from others' problem-centred knowledge, $\chi^2(1, N = 56) = 6.2$, $p < .05$; and (6) marginally, but not significantly more students in the second-year system showed deepening change in problem-centred knowledge from others' problem-centred knowledge, $\chi^2(1, N = 56) = 3.8$, $p < .10$ (see details in Figure 5).

Insert Figure 5 about here

Comparison of Frequencies of Comments

A 2 (Type of CSILE) X 3 (Type of Comment) ANOVA on numbers of comments showed a significant effect for Type of Comment, $F(2, 96) = 7.4$, $p < .05$, and *post hoc* comparisons showed that students in both versions made significantly more information based comments on others' discourse than knowledge-widening and knowledge-deepening comments (Figure 6).

Insert Figure 6 about here

How Students' Progressive Discourse Happened as Information-Flow

Students' discourse in CSILE was analyzed as information-flow between the two different types of knowledge in the solo-plane and the joint-plane. Let me first summarize the information-flow in the two systems.

Information-flow in the solo-plane. The results of the analysis of numbers of knowledge items showed that students in both systems generated similar numbers of knowledge items in total. However, students in the second-year system were more engaged in generating problem-centred knowledge. Furthermore, the results of the analysis of knowledge-change in the solo-plane showed that students in the second-year system were significantly more engaged in knowledge-transforming information-flow (i.e., widening change in referent-centred knowledge from problem-centred knowledge and deepening change in problem-centred knowledge from referent-centred knowledge), whereas students in the first-year system were

more engaged in widening change in problem-centred knowledge from problem-centred knowledge (See Figure 4). Thus, although students in both systems were engaged equally in their interaction with the system, differences in the system affordances are considered to have affected qualities of students' learning activities in the computer-mediated environment. By providing students with discussion notes in the second-year system, the environment helped students keep their problems in their learning track then more flexibly manipulate different types of externalized knowledge in their written discourse.

Information-flow in the joint-plane. As evident in Figure 5, students in the second-year system were significantly more engaged in progressive discourse in the joint-plane of their collaborative learning. They progressed in their written discourse based on others' previous discourse in the database. Although all the patterns of knowledge-changes were not significantly improved, the results of the analysis in the joint-plane showed that the second-year system successfully amplified students' engagement in progressive discourse in the joint-plane.

Differences in System Affordances

The results in this study suggest that it is difficult for students to manage their progressive discourse in a simple note-database such as the first-year system, and they need a clear space such as discussion notes to keep problems in their minds, then collaborate with others. By providing students with interpersonal discourse spaces, the second-year system might prompt students' cognitive process of progressive discourse as follows: First, in the solo-plane, discussion notes might promote students' monitoring of their learning process in a small group. For tracking down their previous thoughts, students no longer have to search their individual notes. They could easily monitor their learning process by scrolling down their discussion notes from the beginning to the end. This support greatly helped students progress their discourse on their problems in the solo-plane.

Second, in the joint-plane, by providing students with opportunities to write collaboratively with the same problems, discussion notes might promote progressive discourse in several knowledge-transforming ways. In the second-year system, students naturally engaged in knowledge-transforming activities in the joint-plane of collaborative learning through coordination among different students' ideas, i.e., transformation of others' knowledge rather than their own knowledge. From a Vygotskian perspective of child development, amplification of joint activities is quite important because interpersonal activities are origins of intrapersonal development (Vygotsky, 1978). Discussion notes as dialectical writing spaces helped students engage in knowledge transformation in such an

interpersonal plane of learning, and facilitate their engagement in knowledge transformation in the intrapersonal plane, i.e., the solo-plane in this study.

Educational Implications

An important finding from the analyses is that knowledge-transformation was amplified in the joint-plane in the second-year system. This transition of the classroom from solo-plane based activity to joint-plane based activity suggests the following educational implications:

From the perspective of a sociocultural approach to human development and learning (e.g., Cole & Engeström, 1993; Vygotsky, 1978; Wertsch, 1985), the transition provides educators with certain possibilities for efficient intervention. As Vygotsky (1978) suggested in his genetic law of human development, the intermental plane of development is the origin of intramental development. Joint-activities with others, mediated by socio-cultural tools, create various learning opportunities for children, i.e., zones of proximal development. In discussion notes, students were involved in their joint-activities with peers, creating various zones of proximal development. The database existed as an arena which represented students' intermental plane of development. Thus, this arena has potential for helping educators to get involved in students' joint-activities as expert learners who supervise students' peer activities.

From the perspective of distributed cognition, the transition from the first- to the second-year system is interpreted as follows. In the second-year system, the classroom changed its structure from a *compilation* of *student-plus* to a *students-plus*. As Perkins (1993) suggested in his notion of distributed cognition, a total cognitive system in which multiple persons collaborate with each other is a real-life distributed cognitive system, "people-plus" developed based on "person-plus." The same notion is included in Engeström's triangular model of general activity (Engeström, 1987). The transition from individual as a cognitive system to a distributed system is a critical change in the activity system itself. In particular, a component "subject" of the system is no longer individual students, but rather groups of students who share their knowledge as a tool for their further development (Engeström, 1987, 1990). Thus, the transition of the system is found to have facilitated a change in the students' activity system itself toward more distributed cognitive system. This change in the activity system suggests a distinct educational implication: the importance of building a "community of expert learners" (Bereiter & Scardamalia, 1993). Schools must change their system from "the traditional transmission model of knowledge from teachers to students," to a "community of learners" in which every student can manifest his/her expertise and contribute to knowledge building in the classroom (Rogoff, 1994). The results in the research partially support the

proposition that students' activities at a community level lead them to higher conceptual progress.

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Table 1. *Eight Categories of Knowledge-Changes Either in the Solo- or the Joint-Plane of Collaborative Learning.*

Preceding Knowledge Item	Change Type	Generated Knowledge Item
Referent-Centred	Widening	Referent-Centred
Referent-Centred	Widening	Problem-Centred
Referent-Centred	Deepening	Referent-Centred
Referent-Centred	Deepening	Problem-Centred
Problem-Centred	Widening	Referent-Centred
Problem-Centred	Widening	Problem-Centred
Problem-Centred	Deepening	Referent-Centred
Problem-Centred	Deepening	Problem-Centred

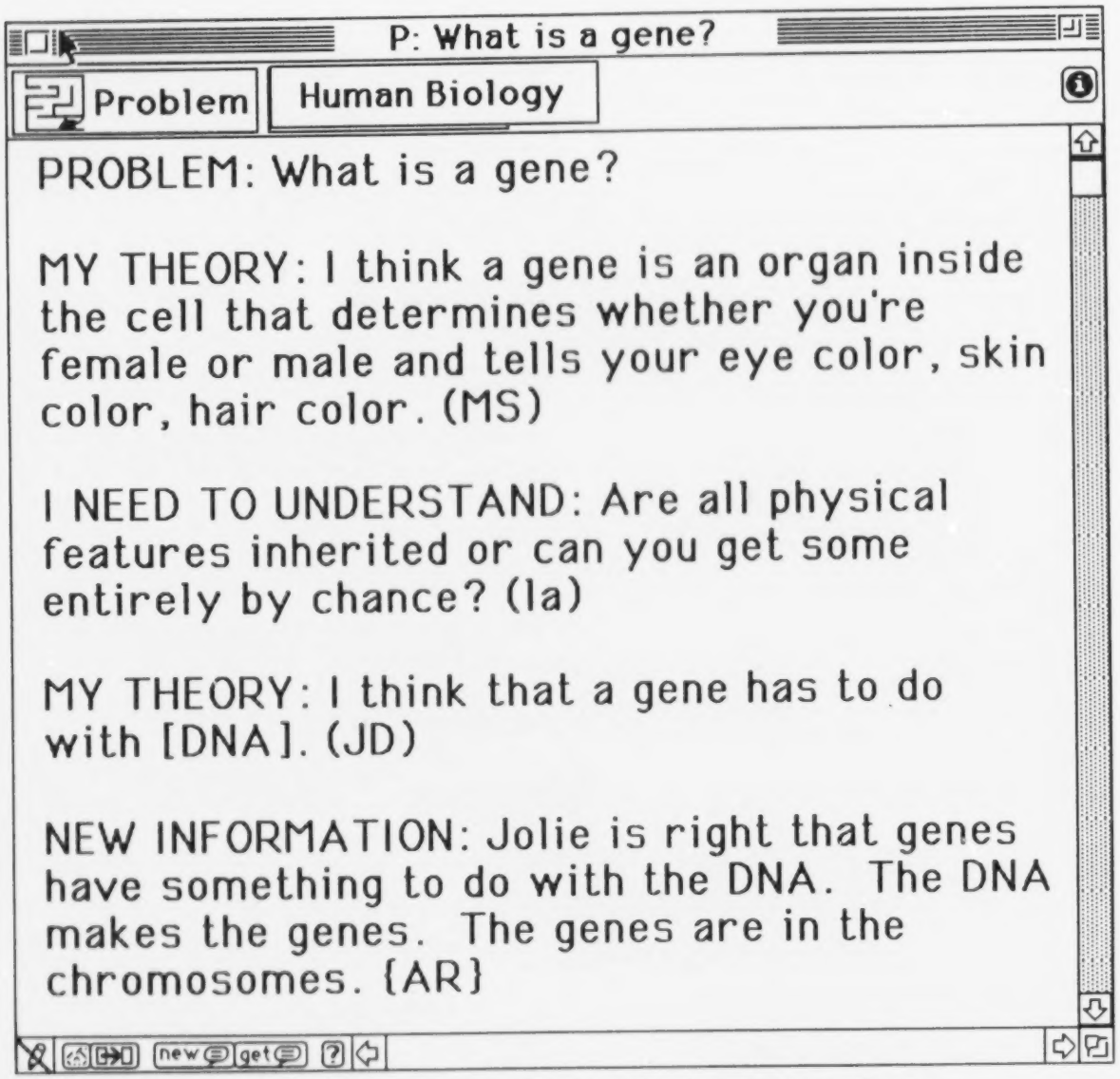

P: What is a gene?
Problem
Human Biology
PROBLEM: What is a gene?
MY THEORY: I think a gene is an organ inside the cell that determines whether you're female or male and tells your eye color, skin color, hair color. (MS)
I NEED TO UNDERSTAND: Are all physical features inherited or can you get some entirely by chance? (Ia)
MY THEORY: I think that a gene has to do with [DNA]. (JD)
NEW INFORMATION: Jolie is right that genes have something to do with the DNA. The DNA makes the genes. The genes are in the chromosomes. {AR}
new
get

Figure 1. An Example of Discussion Note in the Second-Year System.

CS 91-02-27-12:27:30 301
NB 91-02-27-12:27:31
NW 91-02-27-12:53:02 2163
A-> 91-02-27-12:53:02 2163
I THINK ELECTRICITY WORKS LIKE THIS:
(1) First you need some source of energy, which is contained in batteries and can be made by turning something very rapidly like with a hand generator.
(2) To get the energy from the source to the light bulb you need an electricity conductor.
(3) The energy then flows through the electricity conductor at an amazing speed.
[Referent-Centred Knowledge]
(4) When the electricity goes through the tiny wires in the light bulb you can see the electricity and that is how I think the bulb is lit.
(5) When the electricity comes out of the light bulb it goes in to a wire and then back to the source where it repeats the circle until the bulb is either turned of burned out.
[Problem-Centred Knowledge]
<-A
TO 91-02-27-12:53:02 2163 Electricity

Figure 2. An Example of Computer-Tracking Files

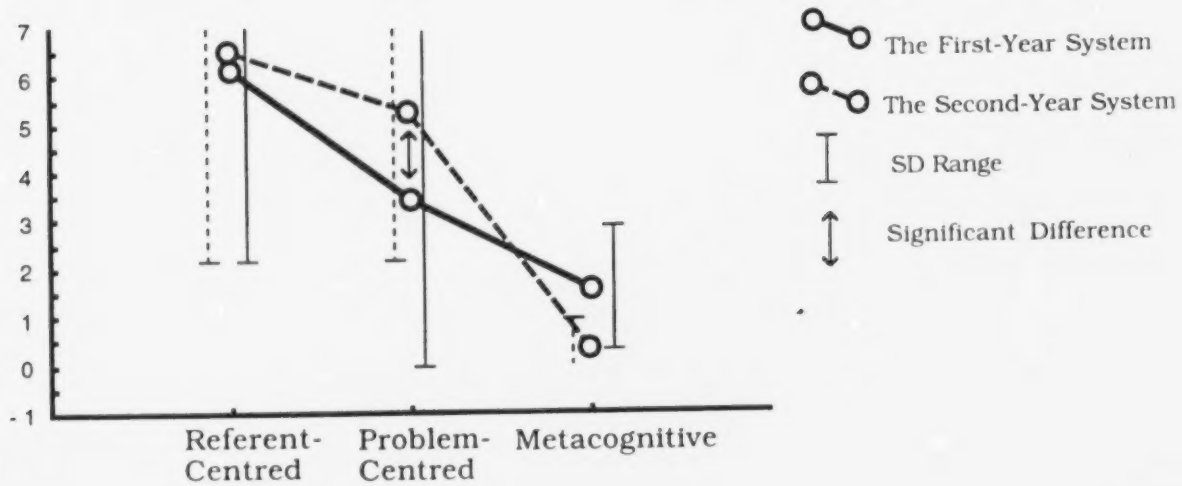


Figure 3. Mean Numbers of Knowledge Items Represented by Students in Two Versions of CSILE.

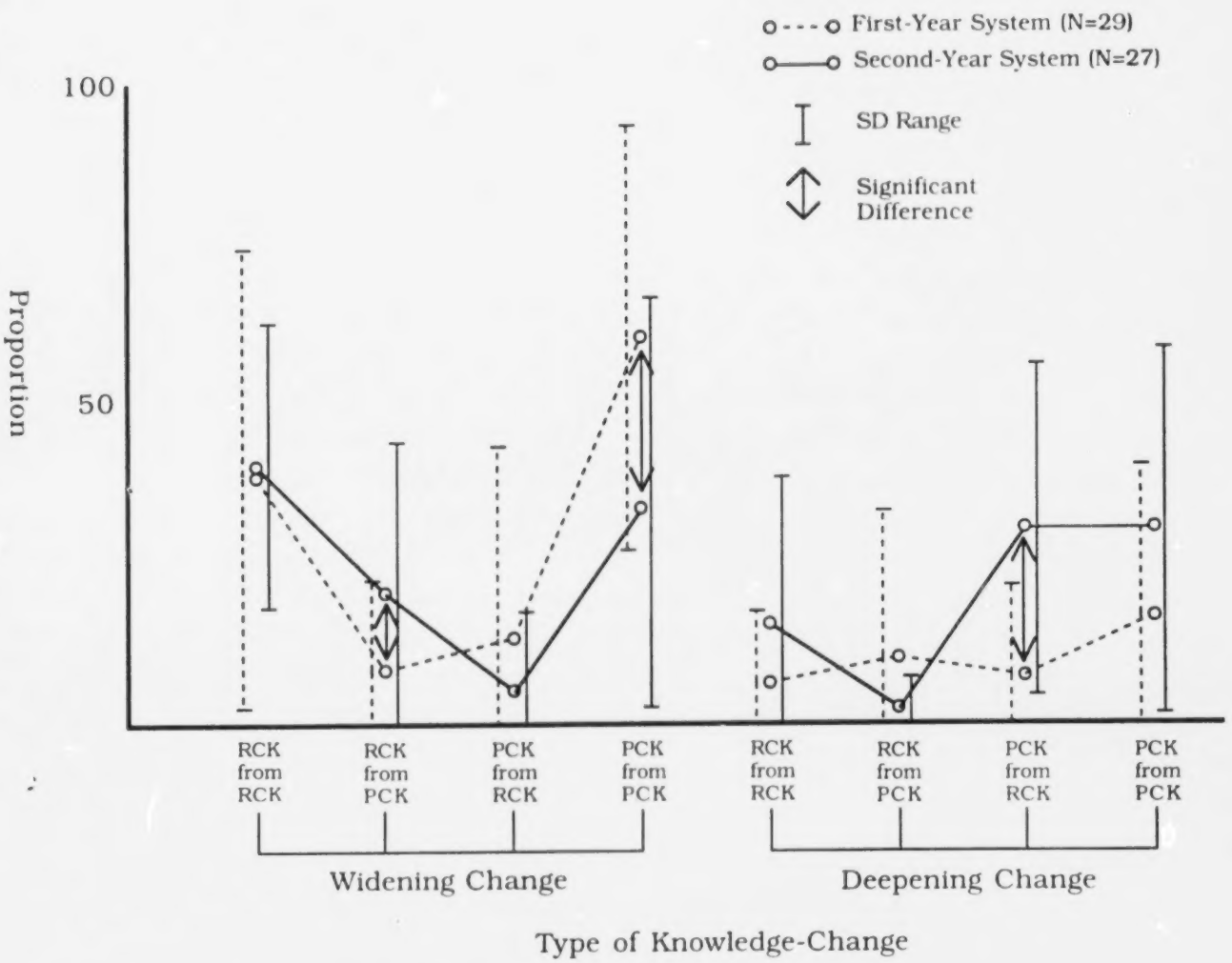


Figure 4. Mean Proportions of Knowledge-Changes in the Solo-Plane.

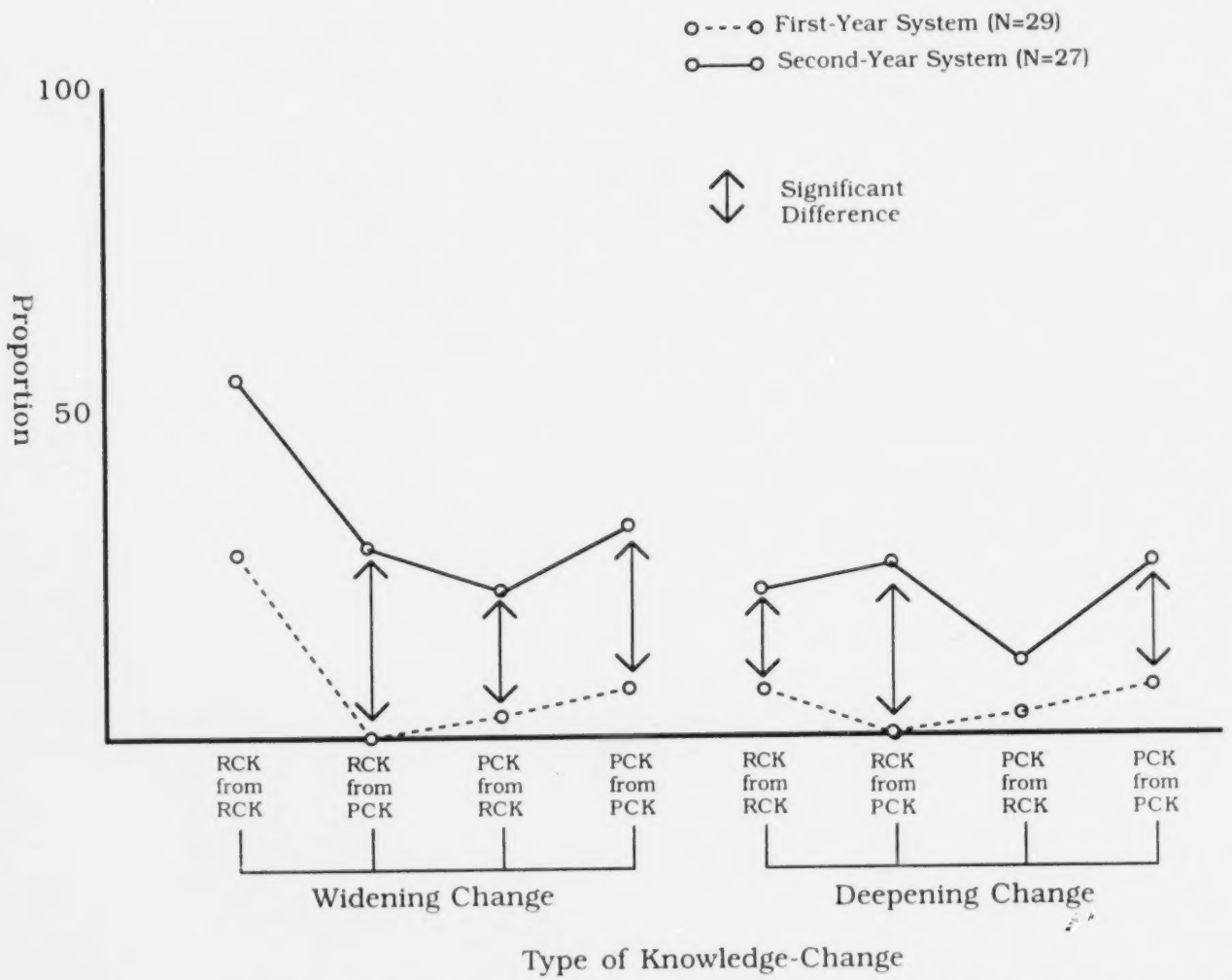


Figure 5. Proportion of Students Who Manifested Different Types of Knowledge-Changes in the Joint-Plane.

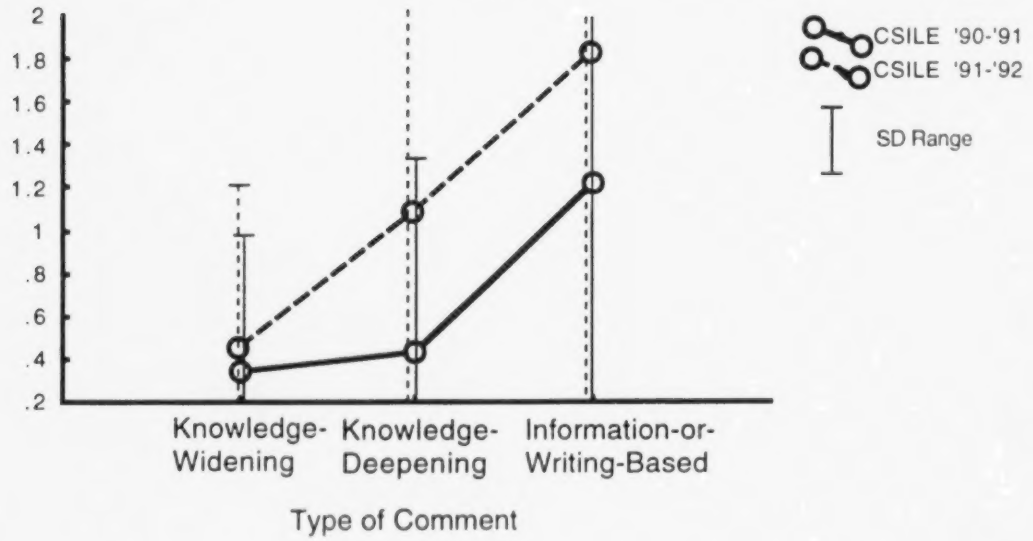
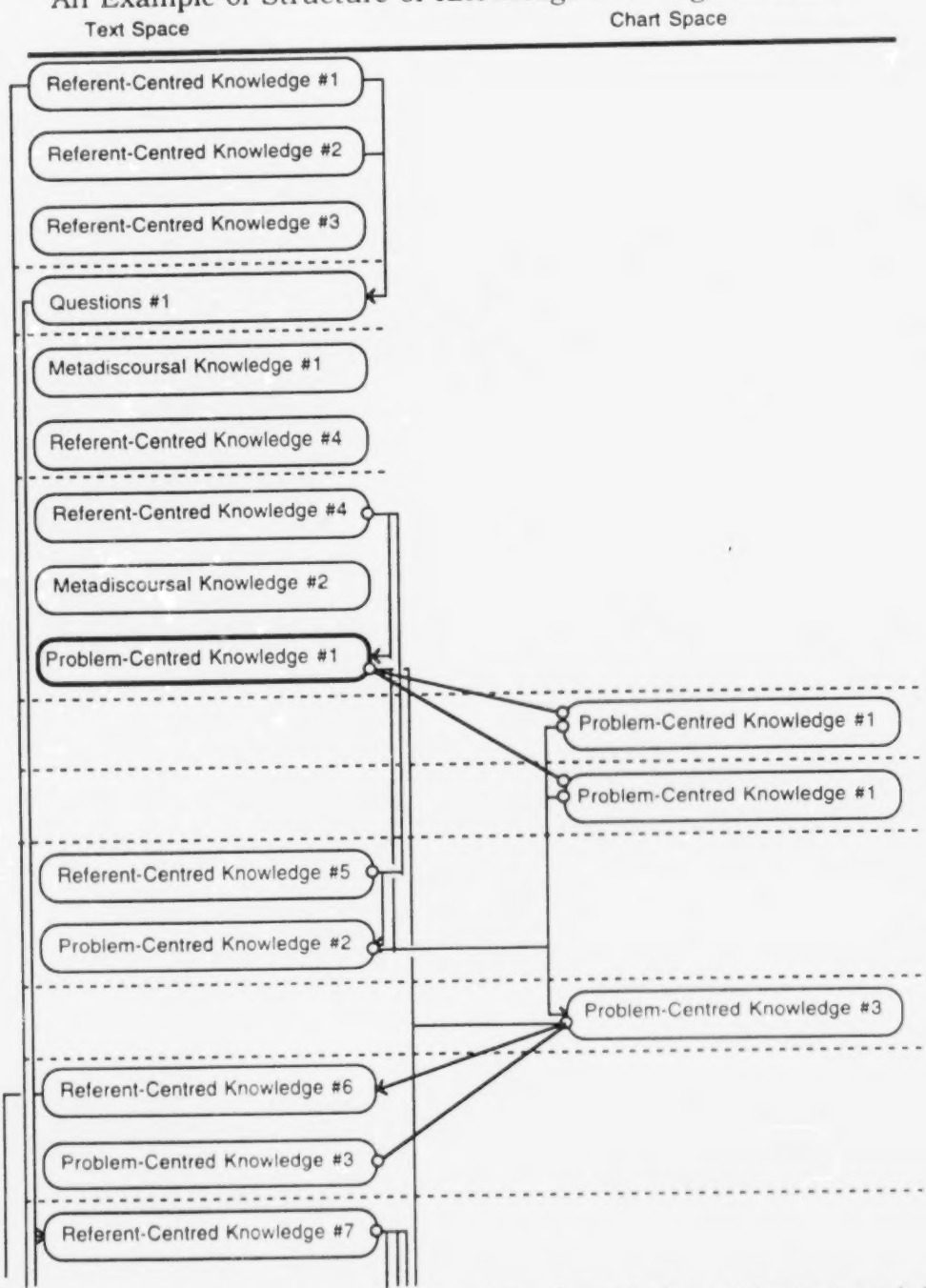


Figure 6. Mean Numbers of Different Types of Comments in Two Versions of CSILE.

Appendix A

An Example of Structure of Knowledge-Building Discourse



Note. A line with a circle and an arrow show knowledge-widening and knowledge-deepening change, respectively. Broken lines represent boundaries between notes in CSILE.

Appendix B

Examples of Knowledge Changes

How I think Electricity Works

...

(7) I think only solids or liquids that are metal or have metal in them will conduct electricity.

...

Why I Think Salt-water Conducts Electricity

(1) Dry salt did not conduct electricity. Plain water did not conduct electricity.

(2) Salt mixed with water does conduct electricity.

(3) I think the reason for this is the salt is a mineral and minerals usually have iron in them, I think the iron inside the salt is conducting the electricity.

An Example of Widening Change in Referent-Centred Knowledge from Preceding Referent-Centred Knowledge

How I Think Electricity Works

(1) I think electricity works like this:there is electricity stored in a battery,and when you hook up a wire to that battery,and to a light bulb,the electricity from that battery runs through the wires,and into the light bulb,and the light bulb lights up.

How I Think A Circuit Works
(1) To make a light bulb light up,there has to be some kind of electric circuit for the electricity to run through.
(2) A circuit is usually made up of a few batteries,two wires and a light bulb.

An Example of Widening Change in Referent-Centred Knowledge from Preceding Problem-Centred Knowledge

I THINK ELECTRICITY WORKS LIKE THIS:

...
(6) The electricity in a power plant could be formed by very large electromagnets.
(7) Wires or thick metal cables would be attached to the electromagnet, hooked up to these wires would be many of the switches and other material used to create a cities electric circuit.

(8) I think that the circuit used to create the elecrticity would have to be parallel because you can keep addiing on to the circuit.
(9) This circuit will stay on even if a light is turned off in house.
...

(5) All of the power that is used so we can have light comes from a source, that source may be an electromagnet that is ten times bigger.
(6) If the electromagnet is in a power plant the electricity would have to travel from the electromagnet, out of the power plant thourgh wires, and out into an electric current.
...
(10) I think the way a light bulb works when it is in a circuit is the beginning of the circuit would be at a power plant, the electricity would flow through the wires under the ground and through the cable poles on the street, into somebody's house, into the wires, and to the socket, into the plugs wires and through the light bulb and back into the current.

An Example of Widening Change in Problem-Centred Knowledge from Preceding Referent-Centred Knowledge

(6) Out of the battery pack comes the electric current (I am going to call it `Electric Current+').
(7) The electric people+ come along out of their home the battery pack.
(8) Soon they come to a S.P.D.T.
(9) They cannot go anywhere until the lever comes down.
(10) When the lever comes down they cross and continue on again to the socket where they are going to meet their friends Electric Current-.
(11) Electric Current- comes the other side of the battery pack and goes through a different S.P.D.T.
(12) Inside the socket Electric Current+ meets Electric Current-.
(13) When the two touch, the light turns on.

(5) In this circut the electricity is making a normal circut except that there are more bulbs and wires.
(6) The '-' energy comes from the '-' side of the battery pack and flows where it is able to.
(7) The '+' energy does the same.
(8) When the two energies meet the light bulb goes on.
(9) I think that because the energy is flowing so fast that it looks like the bulbs turn on imidetily.

An Example of Widening Change in Problem-Centred Knowledge from Preceding Problem-Centred Knowledge

Where Can You Find Electricity?

(1) You can find electricity in everything.
(2) We humans are made of millions of atoms.
(3) So are animals.
(4) So are rocks, trees and plants.
(5) The atoms have electricity inside them, so that means that we have electricity inside us and so do the other things.
(6) Atoms are too small for us to see.
(7) Did you know that there are more atoms at the point of a pencil than there are people on in the world?!
(8) You can't see a atom through anything!

ATOMS

(1) Atoms are made out of protons and neutrons and electrons.
(2) In the middle of a atom, there is a ball called neutrons and near that, some balls, that contains electricity, called protons.
(3) That part is called the NUCLEUS of the atom.
(4) Also there are things that go very fast around the nucleus, they are called electrons.
(5) Each particle is either positive or negative.
(6) The amount of electricity in a particle is called its charge.
(7) A particle with a positive charge and a particle with a negative charge pull weakly at each other if the charges are small and strong if the charges are large.

An Example of Deepening Change in Referent-Centred Knowledge from Preceding Referent-Centred Knowledge

How I Think Electricity Works

* * *

(1) I think electricity works like this: If you had electricity inside you and you wanted to give your freind some electricity so that they would have the same power as you did, you would use a wire or something that would take the power through it and would take it to the other side.
(2) You would hook one side of it to you and the other side to your
friend, then your power would go and meet your friend would have it too.

(3) Another example is: You have two friends.
(4) They don't know each other.
(5) You bring them together, they meet.
(6) Now they each have each other as friends like you had them.

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*** ELECTRICITY***

Try this:
(1) Blow up two balloons. Rub them on a woolen sweater(it might work if you rub it on your hair too) and put on the wall.
(2) It will stick to the wall.
(3) Why does it stick to the wall?
(4) I think the explanation for this is, when you rubed on your woolen sweater(or on your hair), the some of the electrons from the sweater(or your hair) went into the balloon.
(5) So then the balloon had more electrons and it gave of the electrons that were extra to the wall.
(6) But after a short time the balloon will fall from the wall.
(7) That is because the extra electrons in the balloon will leak away

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An Example of Deepening Change in Problem-Centred Knowledge from Preceding Referent-Centred Knowledge

HOW I THINK A HAND GENERATOR WORKS
(1) I think a hand generator work like this.
(2) When you turn the crank that turns a gear which turns another gear connected to the motor.
(3) That makes the motor go and that produces electricity.

HOW I THINK A HAND GENERATOR WORKS
(1) I think a hand generator work like this.
(2) When you turn the crank that turns a gear which turns another gear connected to the motor.
(3) That makes the motor go backwards and since the battery makes the motor turn why can't you turn the motor and make electricity.

An Example of Deepening Change in Problem-Centred Knowledge from Preceding Problem-Centred Knowledge